MEMORANDUM

Subject: Removal Site Evaluation and Preliminary Assessment
Rotary Drilling Site, Inc.
Crystal City, Missouri

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To: Chris Muehlberger
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This memo provides an ecological assessment of the potential impacts of the placement of coal fly ash, sand, and other fill material into a 13-acre wetland area at the Rotary Drilling Site in Crystal City, Missouri. In addition to providing an assessment of the direct impacts to the wetland, the potential off-site impacts to surrounding aquatic areas has also been evaluated. Data collected by Tetra Tech (August, 2011) as part of the removal site evaluation and preliminary assessment was utilized for this ecological assessment. If you have any questions or concerns, please contact me at extension 7794.

WETLAND SOIL EVALAUTION

The ecological impacts of filling a wetland are apparent. The direct physical impact to the wetland environment results in a total loss of ecological habitat. Consequently, the barren landscape is devoid of vegetation, which is the structural building block for an ecosystem. Further, the hydrological component of the wetland has been changed due to the placement of fill. Therefore, the unique wetland characteristics of the site may be irreplaceable. For any kind of ecological habitat to be restored here, revegetation is imperative. However, the potential for natural revegetation to occur here is extremely limited by the fly ash. Although the major constituents of fly ash are similar to those of natural soils and rocks, fly ash has properties that can severely reduce plant growth. These properties include a high pH (and consequent deficiencies of Fe, Mn, Cu, Zn and P), high soluble salts, toxic levels of elements such as boron, cemented/compacted ash layers that inhibit root growth, lack of soil organic matter, and lack of microbial activity.

To evaluate direct eco-toxicological effects on the wetland as well as the potential for natural recovery of the ecosystem, fill material metal concentrations were compared to Ecological Soil Screening Levels (Eco-SSLs) (EPA, 2003) (Table 1). If an Eco-SSL is not available for a particular contaminant, concentrations were compared to ecological screening benchmarks from Oak Ridge National Laboratory (ORNL) for plants and soil invertebrates (Efroymson *et al.*, 1997).

The results of the evaluation of the fly ash shows that antimony, arsenic, barium, boron, chromium, cobalt, copper, lead, nickel, selenium, vanadium and zinc exceed toxicological benchmarks for one or more ecological assessment endpoint (plants, soil invertebrates, mammals and/or birds). Some of the metals that were non-detect also exceeded screening benchmarks (cadmium, thallium). The potential effect of these metals is an uncertainty because the detection limits were higher than the screening benchmarks. Finally, the toxicity of aluminum and iron is primarily controlled by environmental soil factors such as pH and EH. Therefore, the potential toxicity of these metals is an uncertainty as they can't be fully evaluated without having ancillary information, such as soil pH. Finally, essential nutrients such as calcium, magnesium and potassium were not evaluated using toxicological benchmarks. However, these nutrients can become toxic (especially to plant growth) at levels exceeding nutritionally relevant levels.

Because revegetation of the site is a critical to environmental restoration, an evaluation of the toxicity to plants specifically will provide the information necessary to determine the extent of environmental endangerment. Hazard Quotients (HQ) were calculated for contaminants that exceed ecological screening benchmarks for plants. For each contaminant, the 95% UCL of the soil data was compared to the plant screening benchmark. HQ values above 1 indicate potential ecological effects.

Contaminant	HQ
Antimony	2
Arsenic	1
Barium	10
Boron	954
Chromium	48
Cobalt	1
Copper	2
Nickel	1
Selenium	12
Thallium	3

These results indicate that boron toxicity to plants may be a potential limiting factor for revegetation of the filled wetland area (boron HQ = 954). Boron is essential to plant growth at low soil concentrations (0.2-1.5 ppm) yet may produce plant toxicity as the soil concentration increases over 2.5 ppm (Reisenauer *et al.* 1973). The margin between boron sufficiency and toxicity is therefore very narrow for a very wide variety of plants. Concentrations of boron in plant tissue only slightly above the required level have been shown to cause serious injury to the plant (Smith *et al*,. 1997). Boron toxicity also depends on extractability in the soil, as well as the tolerance of various plant species. We screened the boron concentration based on total boron in the fill material, which is an over-estimation of risk as it does not account for the extractable boron. To refine the evaluation of potential risk to boron, extractable boron was assumed to be 10% of the total boron in fill material. Brinton *et al.* (2008) found that as a rule of thumb, to estimate potential effects of total boron in fly ash, 10-30% will be available for plant effects.

Assuming 10% extractable boron, the 95% UCL soil concentration is reduced to 47.7 mg/kg. This concentration still greatly exceeds the levels in which plant toxicity begins to occur (2.5 mg/kg). Therefore, it is highly likely that revegetation of the wetland is not achievable due to boron toxicity in the fly ash, and that irreversible environmental damage has occurred.

OFF-SITE AQAUTIC IMPACTS

In addition to the direct physical and chemical impacts to the wetland, leaching of metal ions (e.g., arsenic, cadmium, chromium, zinc, lead, mercury, selenium) raises concern regarding potential toxic effects on aquatic receptors in the nearby drainage way and Willer's Lake. The physical effect of siltation accompanied by the leaching of metals may lead to chronic impairment of the aquatic system over time. Therefore, the potential indirect impacts to drainage way adjacent to the site, Plattin Creek and Willers Lake due to infiltration and run-off from the fly ash have been evaluated.

To evaluate the impacts of fly ash on the sediment and surface water collected in the Willer's Pond and the drainage to Plattin Creek, we compared the sediment concentrations to background sediment locations (SD-7, SD-8, and SD-9). Sediment concentrations were then compared to the 95% UCL for the same contaminant found in the ash (using ProUCL 4.1). Finally, sediment was compared to ecological screening benchmarks based on Threshold Effect Concentrations (TECs) developed by MacDonald *et al.* (2000) (Table 2). A TEC is not available for all of the metals. For metals in which a TEC is unavailable, a background comparison is all that was done. This decision matrix should inform us if the concentrations found in sediment are coming from the ash and whether or not they are potentially toxic to aquatic life exposed to sediment. The results are as follows:

Sediment concentration similar to background at most locations.	Antimony, Silver, Thallium
Sediment concentration screened against background. Concentrations exceed background, and are similar to or less than ash concentration.	Barium, Beryllium, Boron, Cobalt, Iron, Selenium, Vanadium
Sediment concentration screened against TEC, exceeds TEC, and is similar to fly ash concentration.	Arsenic, Copper, Nickel
Sediment concentration screened against TEC, does not exceed TEC, and is similar to fly ash concentration.	Chromium
Sediment concentration screened against TEC, exceeds TEC, but concentration in sediment is greater than fill material.	Cadmium, Lead, Manganese and Zinc

Most of the metals in sediment exceed background concentrations at levels similar to or less than the concentrations found in fly ash. Therefore, fly ash appears to be gradually contributing to metal contamination in Willer's Pond and the drainage to Plattin Creek. For metals in which a TEC is available, potential aquatic toxicity should be further evaluated. These metals include arsenic, copper, nickel, cadmium, lead, manganese and zinc.

Sediment concentrations for cadmium, lead, manganese, and zinc exceed background levels at concentrations greater than those found in fly ash. At many of the sampling locations, these concentrations also exceed the TEC. That being said, there may be an additional source for these metals causing the concentrations in sediment to exceed the fly ash concentrations. One potential source is the railroad that runs parallel to the drainage way. The rail lines that transport lead from old lead belt, which includes Jefferson County, run through Crystal City. The metals in the drainage way may even be coming directly from the rail ballasts (which were constructed out of chat containing high lead concentrations). Potential sediment toxicity, especially due to lead, is a concern; however, the source for the lead is likely the rail road ballast. For metals not associated with the railroad chat ballasts (arsenic, copper and nickel), the data indicates that fly ash is contributing to concentrations of metals in sediment that are gradually becoming potentially toxic to aquatic life.

Finally, off-site aquatic effects were also evaluated by reviewing surface water concentrations. Surface water concentrations were compared to chronic National Ambient Water Quality Criteria (NAWQC). If a NAWQC was not available, EPA Region 5 Ecological Screening Levels were used (Table 3). Surface water concentrations of barium, boron and manganese exceed background and/or ecological screening benchmarks at all locations. However, at location SW-4, chromium, cobalt, copper, lead, selenium and vanadium also exceed background and/or screening benchmarks. The source of the metals in surface water at SW-4 appears to be related to sediment, as SD-4 shows elevated sediment concentrations as well.

CONCLUSION

The physical and chemical effects to the wetland ecosystem caused by the placement of fill material containing fly ash are substantial. In addition to the altered hydrology and direct destruction of the ecosystem, natural revegetation and restoration of the site is highly unlikely due to the toxic effects of trace elements in fly ash, principally boron. As well, we are beginning to see the gradual and ongoing contamination of the drainage to Plattin Creek and Willer's Lake due to run-off and infiltration from the fly ash pile. Some contaminants (arsenic, copper and nickel) are already at levels exceeding ecological toxicity thresholds for sediment. If the fill material remains in place, additional metals will accumulate in the drainage way and lake, eventually leading to greater aquatic toxicity over time.

Table 1. Concentrations in fly ash at varying depths (mg/kg). Highlighted values exceed one or more of the Eco-SSLs. Concentrations highlighted in green exceed toxicity benchmarks for plants in particular.

Sampling Location	Sample Depth (ft bgs)	Aluminum	Antimony	Arsenic	Barium	Berylium	Boron	Cadmium	Chromium
Eco-SSL Plants		pH >5.5	5.0	18	500	10	0.5	32	1.0
Eco-SSL Soil Invertebrates		pH >5.5	78	60	330	40	NA	140	0.4
Eco-SSL Birds		pH >5.5	NA	43	NA	NA	NA	0.77	26
Eco-SSL Mammals		pH >5.5	0.27	46	2000	21	NA	0.36	34
SB-1	0-2	1270	5.2U	3.8	17.4U	0.43U	12.3U	0.43UJ	3.0
SB-2	10-12	61,300	7.2U	39.2	4270	3.6	538	0.67J	51.2
SB-3	7-9	56300	6.3U	17.1	3950	3.0	406	0.53UJ	33.7
SB-4	24-26	62000	8.3U	50.4	4300	4.0	590	0.69UJ	59.1
SB-5	0-2	61100	6.9U	17.8	4350	3.1	446	0.58UJ	39.1
SB-6	13-15	4300	7.0U	56.2	2200	3.9	424	0.89J	47.9
SF-1	0-2	47200	7.6U	18.2	3610	2.3	423	0.69J	51.7
SF-2	0-2	54800	7.2U	9.8	3560	2.8	269	0.6UJ	27.4
SF-3	0-2	54000	6.1U	8.9	3600	2.6	275	0.51UJ1	22.1
95% UCL (ash)		27816	8.3U	18.05	4778	3.5	477.1	0.89	48.22

Sampling Location	Cobalt	Copper	Iron	Lead	Manganese	Nickel	Selenium	Silver	Thallium	Vanadium	Zinc
Eco-SSL Plants	13.0	70	pH/EH	120	220	38	0.52	560	1.0	NA	160
Eco-SSL Soil Invertebrates	NA	80	pH/EH	1700	450	280	4.1	NA	NA	2.0	120
Eco-SSL Birds	120	28	pH/EH	11	4300	210	1.2	4.2	NA	7.8	46
Eco-SSL Mammals	230	49	pH/EH	56	4000	130	0.63	14	NA	280	79
SB-1	4.3U	4.9	2950	38.7	65.5	5.7	3.0U	0.87U	2.2U	4.6	16.6
SB-2	18.8	137	25300	45.2	172	48.3	6.0	1.2U	2.9U	161	104
SB-3	13.5	105	22100	19.4	149	33.5	3.7U	1.1U	2.6U	129	62.5
SB-4	19.3	142	24200	56.3	223	50.7	5.5	1.4U	3.4U	167	128
SB-5	16.7	122	25000	22.4	150	41.9	4.0U	1.2U	2.9U	143	73.3
SB-6	15.2	94.4	21800	58.9	197	44.8	5.1	1.2U	2.9U	132	137
SF-1	12.5	117	18600	27.9	125	30.2	4.5U	1.3U	3.2U	121	80.7
SF-2	13.6	84.9	25500	10.0	143	34.7	4.2U	1.2U	3.0U	119	52.8
SF-3	13.8	75.4	24800	9.0	138	33.0	3.5U	1.0U	2.5U	108	43.0
95% UCL (ash)	16.93	123.8	31574	43.6	179.1	44.21	6.0	1.4	3.0	139	102.1

Table 2. Concentrations in Sediment (mg/kg). Highlighted values exceed Threshold Effect Concentrations.

Sampling Location	Antimony	Arsenic	Barium	Beryllium	Boron	Cadmium	Chromium	Cobalt	Copper
Screening Level	6.7 (average background)	9.79	74 (average background)	0.58 (average background)	11.2 (average background)	0.99	43.4	6.1 (average background)	31.6
RDS-SD-1	5.1	5.3	98.9	0.75	8.4	2.0	11.6	16.3	59.1
RDS-SD-2	5.3U	20.0	2100	1.7	90.9	0.79J	29.4	12.8	88.2
RDS-SD-2-FD	5.5U	11.4	780	1.1	53.5	2.2	19.3	20.3	96.5
RDS-SD-3	8.0	6.3	719	0.67	23.7	0.68	14.5	7.6	69
RDS-SD-4	5.3U	26.8	3050	2.5	193	0.77J	46.1	14.3	103
RDS-SD-5	4.9	12.4	1310	1.5	57.9	0.86	30.5	10.8	65.1
RDS-SD-6	5.3U	8.1	491	0.75	28.8	1.0J	18.7	7.5	48.8

Sampling Location	Iron	Lead	Manganese	Nickel	Selenium	Silver	Thallium	Vanadium	Zinc
Screening Level	9,366 (average background)	35.8	182 (average background)	22.7	3.9 (average background)	1.1 (average background)	2.8 (average background)	19.8 (average background)	121
RDS-SD-1	13600	587	792	20.4	3.0	0.84U	2.1	19.7	183
RDS-SD-2	15800	124	1510	27.9	16.5	0.89U	2.2U	76.6	106
SD-2-dup	16500	637	866	31.3	7.1	0.91U	2.3U	47.1	197
RDS-SD-3	8480	239	739	13.1	4.7	1.3	3.3	18.2	99
RDS-SD-4	18400	62.4	547	35.5	9.7	0.88U	2.2U	93.9	117
RDS-SD-5	17400	83.2	1230	26.8	2.9	0.82U	2.1	59.5	156
RDS-SD-6	15000	107	768	17.1	3.1U	0.88U	2.2U	30.8	204

Table 3. Concentrations in Surface Water (µg/L). Highlighted values exceed Chronic Water Quality Criteria or the Region 5 Ecological Screening Level.

Sampling Location	Antimony	Arsenic	Barium	Beryllium	Boron	Cadmium	Chromium	Cobalt
Screening Level (µg/L)	80	150	3.9	5.1	43.7 (average background)	0.25	10.0	3.0
RDS-SW-1	2.0U	1.0U	108	1.0U	293	1.0U	2.0	1.5
RDS-SW-2	2.0U	3.8U	148	1.0U	651	1.0U	2.0	1.0
RDS-SW-2-FD	2.0U	3.7U	140	1.0U	618	1.0U	2.0	1.0
RDS-SW-3	2.0U	4.0	151	1.0U	664	1.0U	2.0	1.0
RDS-SW-4	2.0U	29.7	309	1.0U	4040	1.0U	15.0	3.4
RDS-SW-5	2.0U	1.0U	103	1.0U	156	1.0U	2.0	1.0
RDS-SW-6	2.0U	1.0U	95.0	1.0U	119	1.0U	2.0	1.0

Sampling Location	Copper	Lead	Manganese	Nickel	Selenium	Silver	Thallium	Vanadium	Zinc
Screening Level	11	2.5	80	160	5.0	0.12	10	19	100
RDS-SW-1	2.1	9.9	641	3.6	5.0	1.0U	1.0U	5.0U	6.2
RDS-SW-2	2.7	2.4	282	3.8	7.0	1.0U	1.0U	5.0U	3.9
RDS-SW-2-FD	2.6	2.6	267	3.6	7.4	1.0U	1.0U	5.0U	3.5
RDS-SW-3	2.9	2.0	222	3.4	7.5	1.0U	1.0U	5.0U	2.3
RDS-SW-4	23.8	31.1	421	14.5	25.7	1.0U	1.0U	51.0	48.3
RDS-SW-5	2.0	1.0	212	2.2	5.0	1.0U	1.0U	5.0U	2.7
RDS-SW-6	2.0	1.0	63.3	1.7	5.0	1.0U	1.0U	5.0U	2.7

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